Speciation-analysis for Recycling of Critical Elements in Aqueous Waste Streams

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1 Presence of Critical Elements in Waste Streams

Limited availability of inorganic commodities is one of the largest challenges for a future sustainable material use as set by European Commission. Growing life standards, demand for mobility and electronic devices require more and more specialty materials. Combining this economic importance and their supply risk, a class of critical materials is defined.

Platinum Group Metals

PGM's include platinum (Pt), rhodium (Rh), palladium (Pd), iridium (Ir), ruthetium (Ru) and osmium (Os). They possess unique properties, making them indispensable in autocatalysts, jewelry, electrical and electronical applications and industrial catalysts. PGM prices, with Pt being the far most important, have seriously risen in the last years (*Table 1*).

Table 1. *Overview of PGM prices and the current fracition of recycling.* [1]

ELEMENT	PRICE (€ kg^{-1})	CURRENT RECYCLED FRACTION (%)
Platinum	38,240	24
Rhodium	26,520	26
Palladium	21,500	26
Irridium	14,940	25-50
Osmium	9,790	0
Ruthenium	1,850	10-25

Rare Earth Elements

REE's comprehend 17 elements with a large chemical similarity, essential in i.a. permanent magnets and related 'clean energy' applications such as wind turbines, rechargeable batteries and electric vehicles. Tight export quota set by the world's largest exporting country of REE's, China, hardly meet this rising demand. [2]

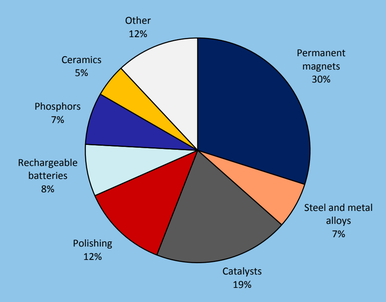

Figure 1. *Applications which involve REE's with their relative fraction of overall REE use.* [3]

Table 2. *Main elemental composition of REE based applications.*

APPLICATION	ELEMENTS
Permanent magnets	Nd, Pr, Dy, Gd
Catalysts	Ce, La, Nd, Pr
Polishing	Ce, La, Pr
Rechargeable batteries	La, Ce, Nd, Pr, Sm
Steel and metal alloys	Ce, La, Nd, Pr
Phosphors	Y, Ce, La, Eu, Tb, Gd
Ceramics	Y, La, Ce, Nd, Pr
Other	Ce, La, Y, Nd, Pr, Sm, Gd

Presence
of Critical Elements
in Waste Streams

2 Focus on Recycling Strategies

- Along with political and strategic considerations, alternative sources for these materials are considered vital. Having a non-geographically bounded supply, recycling and **"urban mining"** have strong economic advantages besides primary mining.
- Efforts and possibilities in processing solid waste streams of critical elements is growing. [4] However, scientific and technical expertise are missing effective strategies for **liquid media**. Although some PGM's and REE's are toxic, absence of discharge limits in the current legislation certainly contributes to this. [5]
- The ongoing research focusses on developing strategies to recover and recuperate valuable elements in wastewaters. The value of potential recuperation is considerable to overcome operational costs. **(Bio)medical use of platinum** for example, extends to 8290 ton of platinum demand, representing a worldwide (input) value of 255 million EUR.

Focus
on Recycling
Strategies

3 Speciation-analysis as Analytical tool

Where quantification reveals information on the scale, chemical determination guides towards well-aimed recovery strategies. Characterisation by speciation-analysis is key to fully understand the target's nature. However strictly inorganic, these elements are associated with ligands and functionalities, especially considering their matrix.

- A screening for platinum content in several waste water was performed. **Microfiltration** was used to distinguish between soluble or particulate matter.
- In order to overcome challenging detection limits, **Solid Phase Extraction** was evaluated for the pre-concentration of species (*Figure 2*).
- Further techniques, such as **Reversed Phase HPLC-ICP-QMS** differentiate between species of select elements. The originally applied versus degraded products could be revealed.

Based hereupon, different removal techniques such as adsorption were tested at lab scale.

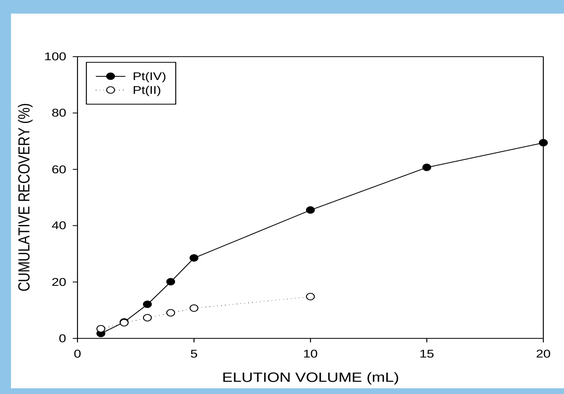

Figure 2. *Recovery profile of platinum chloride species in Solid Phase Extraction (SPE) experiment. Initial loading of 27.1 ng Pt(IV) and 65.4 ng Pt(II) were eluted with 0.1 M thiourea, 0.1 M HCl at 60 ° C. Adsorption effiencies of 98% for Pt(IV) and 94% for Pt(II) were obtained.*

Speciation
as Analytical tool

4 Outlook

- Clarify the current **distribution** of critical elements **in the environment** for Flanders.
- Study the influence of urine and wastewater **matrix** on the removal process.
- Further **optimisation** of chromatographic conditions for speciation of platinum chloride complexes.

Outlook

References

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